LM431
Adjustable Precision Zener Shunt Regulator

General Description
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V (VREF) up to 36V merely by selecting two external resistors that act as a voltage divided network. Due to the sharp turn-on characteristics this device is an excellent replacement for many zener diode applications.

Features
- Average temperature coefficient 50 ppm/˚C
- Temperature compensated for operation over the full temperature range
- Programmable output voltage
- Fast turn-on response
- Low output noise

Connection Diagrams

Ordering Information (Note 1)

<table>
<thead>
<tr>
<th>Package</th>
<th>Typical Accuracy</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5%</td>
<td>1%</td>
</tr>
<tr>
<td>TO-92</td>
<td>LM431CCZ</td>
<td>LM431BCZ</td>
</tr>
<tr>
<td></td>
<td>LM431CIZ</td>
<td>LM431BIZ</td>
</tr>
<tr>
<td>SO-8</td>
<td>LM431CCM</td>
<td>LM431BCM</td>
</tr>
<tr>
<td></td>
<td>LM431CIM</td>
<td>LM431BIM</td>
</tr>
<tr>
<td>SOT-23</td>
<td>LM431CCM3</td>
<td>LM431BCM3</td>
</tr>
<tr>
<td></td>
<td>LM431CIM3</td>
<td>LM431BIM3</td>
</tr>
</tbody>
</table>

Note 1: See Table 1 for package marking for SOT-23.
Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Storage Temperature Range  
−65˚C to +150˚C

Operating Temperature Range

Industrial (LM431xI)  
−40˚C to +85˚C

Commercial (LM431xC)  
0˚C to +70˚C

Lead Temperature

TO-92 Package/SO-8 Package/SOT-23 Package
(Soldering, 10 sec.) 265˚C

Internal Power Dissipation (Notes 3, 4)

<table>
<thead>
<tr>
<th>Package Type</th>
<th>Internal Power Dissipation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO-92</td>
<td>0.78W</td>
</tr>
<tr>
<td>SO-8</td>
<td>0.81W</td>
</tr>
<tr>
<td>SOT-23</td>
<td>0.28W</td>
</tr>
</tbody>
</table>

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

Operating Conditions

Cathode Voltage  
37V

Continuous Cathode Current  
−10 mA to +150 mA

Reference Voltage  
−0.5V

Reference Input Current  
10 mA

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Electrical Characteristics

$T_A = 25˚C$ unless otherwise specified

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{REF}}$</td>
<td>Reference Voltage</td>
<td>$V_Z = V_{\text{REF}}, I_Z = 10 \text{ mA}$</td>
<td>2.440</td>
<td>2.495</td>
<td>2.550</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LM431A (Figure 1 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_Z = V_{\text{REF}}, I_Z = 10 \text{ mA}$</td>
<td>2.470</td>
<td>2.495</td>
<td>2.520</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LM431B (Figure 1 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_Z = V_{\text{REF}}, I_Z = 10 \text{ mA}$</td>
<td>2.485</td>
<td>2.500</td>
<td>2.510</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LM431C (Figure 1 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{\text{DEV}}$</td>
<td>Deviation of Reference Input Voltage Over Temperature (Note 5)</td>
<td>$V_Z = V_{\text{REF}}, I_Z = 10 \text{ mA}$, $T_A = \text{Full Range (Figure 1 )}$</td>
<td>8.0</td>
<td>17</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>$\Delta V_{\text{REF}}$</td>
<td>Ratio of the Change in Reference Voltage to the Change in Cathode Voltage</td>
<td>$I_Z = 10 \text{ mA}$, $V_Z$ from $V_{\text{REF}}$ to 10V (Figure 2 )</td>
<td>−1.4</td>
<td>−2.7</td>
<td></td>
<td>mV/V</td>
</tr>
<tr>
<td>$\Delta V_Z$</td>
<td></td>
<td>$V_Z$ from 10V to 36V (Figure 2 )</td>
<td>−1.0</td>
<td>−2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{\text{REF}}$</td>
<td>Reference Input Current</td>
<td>$R_1 = 10 \text{ k\Omega}, R_Z = \infty, I_I = 10 \text{ mA}$ (Figure 2)</td>
<td>2.0</td>
<td>4.0</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$\Delta I_{\text{REF}}$</td>
<td>Deviation of Reference Input Current over Temperature</td>
<td>$R_1 = 10 \text{ k\Omega}, R_Z = \infty, I_I = 10 \text{ mA,} T_A = \text{Full Range (Figure 2 )}$</td>
<td>0.4</td>
<td>1.2</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$I_{\text{(MIN)}}$</td>
<td>Minimum Cathode Current for Regulation</td>
<td>$V_Z = V_{\text{REF}}$ (Figure 1 )</td>
<td>0.4</td>
<td>1.0</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{\text{(OFF)}}$</td>
<td>Off-State Current</td>
<td>$V_Z = 36V, V_{\text{REF}} = 0V$ (Figure 3 )</td>
<td>0.3</td>
<td>1.0</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$r_Z$</td>
<td>Dynamic Output Impedance (Note 6)</td>
<td>$V_Z = V_{\text{REF}}, LM431A$, Frequency = 0 Hz (Figure 1 )</td>
<td>0.75</td>
<td></td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_Z = V_{\text{REF}}, LM431B, LM431C$, Frequency = 0 Hz (Figure 1 )</td>
<td>0.50</td>
<td></td>
<td></td>
<td>Ω</td>
</tr>
</tbody>
</table>

Note 3: $T_{J_{\text{Max}}} = 150˚C$.

Note 4: Ratings apply to ambient temperature at 25˚C. Above this temperature, derate the TO-92 at 6.2 mW/˚C, the SO-8 at 6.5 mW/˚C, and the SOT-23 at 2.2 mW/˚C.
**LM431**

**Electrical Characteristics** (Continued)

**Note 5:** Deviation of reference input voltage, \( V_{DEV} \), is defined as the maximum variation of the reference input voltage over the full temperature range.

\[
V_{DEV} = V_{MAX} - V_{MIN}
\]

Where:

\[ T_2 - T_1 = \text{full temperature change.} \]

\( \alpha \) \( V_{REF} \) can be positive or negative depending on whether the slope is positive or negative.

Example:

\[ V_{DEV} = 8.0 \text{ mV}, V_{REF} = 2495 \text{ mV}, T_2 - T_1 = 70^\circ C, \text{ slope is positive.} \]

**Note 6:** The dynamic output impedance, \( r_Z \), is defined as:

\[
r_Z = \frac{\Delta V_Z}{\Delta I_Z}
\]

When the device is programmed with two external resistors, \( R_1 \) and \( R_2 \), (see Figure 2), the dynamic output impedance of the overall circuit, \( r_Z \), is defined as:

\[
r_Z = \frac{\Delta V_Z}{\Delta I_Z} = r_Z \left( 1 + \frac{R_1}{R_2} \right)
\]
Equivalent Circuit

DC Test Circuits

Note: $V_Z = V_{REF} \cdot \frac{1 + R_1}{R_2} + I_{REF} \cdot R_1$

FIGURE 1. Test Circuit for $V_Z = V_{REF}$

FIGURE 2. Test Circuit for $V_Z > V_{REF}$

FIGURE 3. Test Circuit for Off-State Current
**Typical Performance Characteristics**

**Input Current vs V\(_Z\)**

![Input Current vs V\(_Z\)](image)

**Thermal Information**

![Thermal Information](image)

**Input Current vs V\(_Z\)**

![Input Current vs V\(_Z\)](image)

**Dynamic Impedance vs Frequency**

![Dynamic Impedance vs Frequency](image)

**Stability Boundary Conditions**

![Stability Boundary Conditions](image)

*Note:* The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R\(_2\) and V\(_\text{+}\) were adjusted to establish the initial V\(_Z\) and I\(_Z\) conditions with C\(_L\) = 0. V\(_\text{+}\) and C\(_L\) were then adjusted to determine the ranges of stability.

**Test Circuit for Curve A Above**

![Test Circuit for Curve A Above](image)

**Test Circuit for Curves B, C and D Above**

![Test Circuit for Curves B, C and D Above](image)
Typical Applications

Shunt Regulator

\[ V_O = \left( 1 + \frac{R_1}{R_2} \right) V_{REF} \]

Series Regulator

\[ V_O = \left( 1 + \frac{R_1}{R_2} \right) V_{REF} \]

Single Supply Comparator with Temperature Compensated Threshold

\[ V_{CN} = 2 \text{ V} \]
\[ V_{IH} = 2.5 \text{ V} \]
\[ V_{OFF} = V_{EE} \]

Output Control of a Three Terminal Fixed Regulator

\[ V_O = \left( 1 + \frac{R_1}{R_2} \right) V_{REF} \]
\[ V_{MIN} = V_{REF} + 5 \text{ V} \]

Higher Current Shunt Regulator

\[ V_O = \left( 1 + \frac{R_1}{R_2} \right) V_{REF} \]

Crow Bar

\[ V_{LIMT} = \left( 1 + \frac{R_1}{R_2} \right) V_{REF} \]
Typical Applications (Continued)

Over Voltage/Under Voltage Protection Circuit

Low Limit = \( V_{\text{REF}} \left( 1 + \frac{R_{1B}}{R_{2B}} \right) + V_{\text{BE}} \)

High Limit = \( V_{\text{REF}} \left( 1 + \frac{R_{1A}}{R_{2A}} \right) \)

Voltage Monitor

Low Limit = \( V_{\text{REF}} \left( 1 + \frac{R_{1B}}{R_{2B}} \right) \)

LED ON WHEN LOW LIMIT < V < HIGH LIMIT

High Limit = \( V_{\text{REF}} \left( 1 + \frac{R_{1A}}{R_{2A}} \right) \)
Typical Applications (Continued)

### Delay Timer

\[
\text{DELAY} = R \cdot C \cdot \frac{1}{(V^+ - V_{\text{REF}})}
\]

### Current Limiter or Current Source

\[
I_O = \frac{V_{\text{REF}}}{R_{CL}}
\]

### Constant Current Sink

\[
b = \frac{V_{\text{REF}}}{R_S}
\]

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**Recommended Solder Pads for SOT-23 Package**

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**TABLE 1. Package Marking for SOT-23**

<table>
<thead>
<tr>
<th>Order Number</th>
<th>Top Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM431ACM3</td>
<td>N1F</td>
</tr>
<tr>
<td>LM431AIM3</td>
<td>N1E</td>
</tr>
<tr>
<td>LM431BCM3</td>
<td>N1D</td>
</tr>
<tr>
<td>LM431BIM3</td>
<td>N1C</td>
</tr>
<tr>
<td>LM431CCM3</td>
<td>N1B</td>
</tr>
<tr>
<td>LM431CIM3</td>
<td>N1A</td>
</tr>
</tbody>
</table>
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2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

Order Number LM431ACZ, LM431AIZ, LM431BCZ, LM431BIZ, LM431CCZ, or LM431CIZ
NS Package Number Z03A